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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
14 November 2002 (14.11.2002)

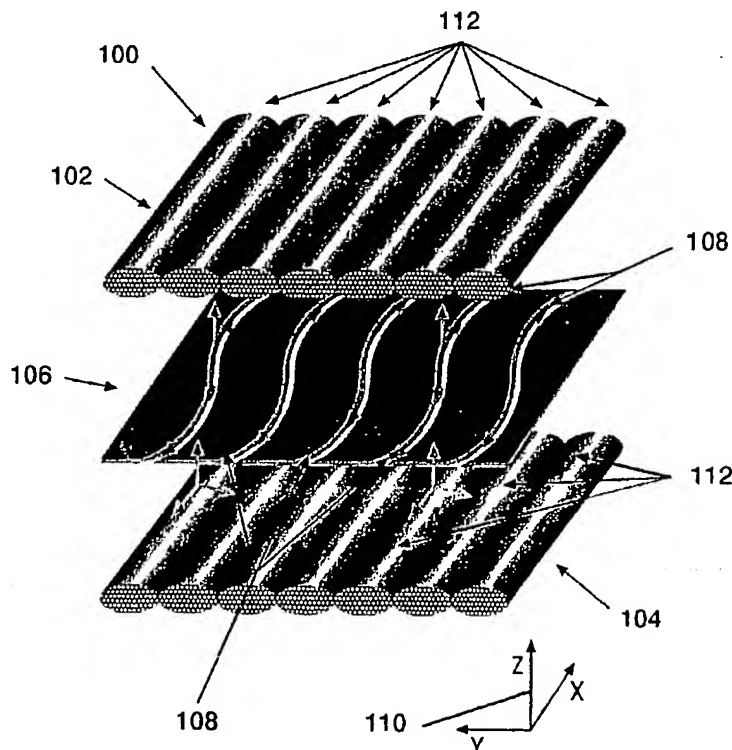
PCT

(10) International Publication Number
WO 02/090089 A1

- (51) International Patent Classification⁷: B29C 70/46, 70/54, B32B 27/12
- (21) International Application Number: PCT/GB02/02055
- (22) International Filing Date: 8 May 2002 (08.05.2002)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
0111278.8 9 May 2001 (09.05.2001) GB
0130965.7 27 December 2001 (27.12.2001) GB
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- (81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),

[Continued on next page]

(54) Title: **MOULDING MATERIAL WITH VENTILATING STRUCTURE FOR ENTRAPPED GASES**



(57) Abstract: A moulding material comprising a layer of a reinforcement material, and a layer of a resin material, the resin material layer comprising a venting structure to allow gases to pass out of the moulding material via the reinforcement layer during processing. The venting structure comprises venting passages or channels for venting the moulding material.

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European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

MOULDING MATERIAL

The present invention relates to a moulding material, particularly but not exclusively to a moulding material comprising a uni-directional fibrous reinforcement material.

Composite moulding materials comprise a resin material and a fibrous reinforcement material. The viscosity of the resin material is strongly influenced by the resin temperature. During processing, on heating the resin, the resin viscosity drops, allowing it to flow around the fibrous reinforcement material. However, as the resin material is heated beyond a certain point (activation temperature), the catalysts within it begin to react and the cross linking reaction of the resin molecules accelerates. The progressive polymerisation increases the viscosity of the resin until it has passed a point beyond which it will not flow at all ('no flow point'). To further promote the flow of the resin material into the reinforcement material, pressure is applied to the moulding formed from the composite moulding material. Often, pressure is applied by the application of vacuum pressure to the moulding.

Historically, moulded articles or mouldings were formed from a resin material either on its own or reinforced with a fibrous reinforcement material. Although the products thus formed were satisfactory, it was difficult to guarantee the quality of the product due to the difficulty in controlling the ratio of the resin material to the fibrous reinforcement material. Another problem encountered in these materials was the entrapment of volatile gases during processing and curing of the material which caused voids in the cured laminate. The process was therefore refined such that the supplier of the resin provided the producer of the moulded article with a

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preform or pre-fabricated moulding material comprising reinforcement materials which were pre-impregnated with a resin material. These moulding materials are known as prepregs.

5 The prepreg moulding material allowed the fabricator to produce moulded articles of a consistent quality. The prepreg material also enabled the fabricator to lay up a combined layer of reinforcement fibrous material and resin material at once.

10 A problem associated with prepreg materials is that voids occur in the cured product due to the presence of intra- and inter-laminar gases which become trapped during processing of the prepreg material. The voids in moulded products are roughly divided into two groups, namely intra-
15 layer voids which develop within respective prepreg layers due to the presence of intra-laminar gases and/or air (i.e. gases trapped within individual prepreg layers of a laminate structure), and interlayer voids which develop between prepreg layers due to the presence of interlaminar
20 gases (i.e. gases trapped between prepreg layers). The causes of the development of both interlayer voids and intralayer voids include volatile matters resulting from water and solvents contained in the prepreg resin, bubbles formed from air which has remained in the resin, etc.. The
25 predominant cause of interlayer voids is conceivably accumulated air which has been taken in between the prepreg layers during lamination and left behind there. This air is easily trapped between the tacky external surfaces of the prepreg layers during the lay-up of the prepreg. Such
30 voids can result in the laminate having poor structural properties and can lead to premature failure of the composite material. Further, these voids result in a poor cosmetic quality finish of the cured product.

 US-A-5104718 (Asada et al.) discloses a
35 unidirectionally paralleled fiber reinforced thermo-setting

*implies lay-up
over an
extrusion*

resin prepreg having plural grooves arranged continuously in longitudinal direction on at least one side surface thereof. The grooves enable the passage of air during moulding and hence no accumulation of interlaminar air occurs. Also, at the time of moulding, the grooves serve as the passage of resin containing volatile matters and air and, together with the help of lateral shift of fibres surrounding the grooves, ultimately give a good moulded product free from interlayer voids (col. 3, lines 1 to 6).

10 The material as disclosed in US-A-5104718 has several important disadvantages. The grooves only act as conduits to interlaminar gases and air. Intralaminar voids therefore still occur. Furthermore, as the grooves are located on the external surface of a prepreg layer, the grooves get clogged and thus blocked. Also, if too much pressure is applied on the prepreg layer during lay-up, the grooves distort which affects venting via the grooves. Also, if the grooves are too shallow or if they have the wrong shape, they get clogged immediately when a further prepreg layer is located thereon. If the groove is too deep, the prepreg has a lower lateral strength and is liable to tear. Also, the groove affects the cosmetic quality of the moulding as it is present on the moulded surface. Finally, the process of forming a grooved prepreg material is complicated and generally expensive as it requires an extra groove applying step after preimpregnation of the reinforcement material.

20 We have discovered that the above problems can be largely reduced or overcome by a moulding material comprising a layer of resin material and conjoined to at least one surface thereof a fibrous layer, the fibrous layer allowing entrapped laminar gases to pass out of the material during processing of the material. Upon curing of this breathable moulding material, entrapped gases escape via the dry reinforcement layer, which prevents these voids from occurring. This material is disclosed in more detail

in WO 00/27632 (Ness et al.) which is incorporated herein by reference.

We have also discovered that the quality of the cured product depends on the processing conditions of the moulding material. To process a breathable moulding material, the processing conditions must be carefully controlled to prevent gases and air from being trapped in the material.

This is particularly important for breathable moulding materials which comprise uni-directional fibrous reinforcement layers. In Figure 1 of the drawings, a diagrammatic plan view is presented of a preform moulding material 10 comprising a layer of a resin material 12 sandwiched between layers of a unidirectional fibrous reinforcement material 14. As the moulding material starts to wet out during processing, areas 18 of the uni-directional fibre become trapped off or blocked by the resin 12 so that no air transport can occur in directions along the reinforcement fibre and perpendicular to the reinforcement fibre (x, y -direction and z -direction). Any residual laminar gases inside the fibre tows of the uni-directional material 14 get locked inside the tows 20 which results in interlayer and intralayer void areas in the cured product.

This problem can occur for a wide range of moulding materials with both woven and unwoven reinforcement layers. However in woven and stitched venting (breathable) moulding materials the problem occurs less frequently. Although we do not wish to be bound by any theory, we believe that both woven and stitched reinforcement material layers provide transport of gases within the plane of the reinforcement materials. Gases are therefore less likely to be trapped by the resin during processing of the material. However, the processing conditions of these materials must also be carefully controlled to prevent gas entrapment.

Problems of gas entrapment in moulding materials with venting properties are particularly present during curing of moulding materials which comprise one or more layers of a uni-directional fibrous reinforcement material or a non-uniform fibrous reinforcement material.

It is therefore desirable to provide an improved moulding material and a method of forming said moulding material, for a more efficient fabrication of moulded articles with a minimal void content, thereby addressing the above-described problems and/or which offers improvements generally.

In embodiments of the present invention, there are provided a moulding material, a resin material, a method of manufacturing a moulding material, a method of manufacturing a resin material and a moulded article as defined in the accompanying claims.

In an embodiment of the invention, there is provided a preform multi-layered moulding material comprising a layer of a reinforcement material, and a layer of a resin material, the resin material layer comprising a first venting structure to allow interlaminar and intralaminar gases to pass out of said moulding material via the reinforcement layer during processing. The resin layer thus acts as a conduit for both interlaminar gases and intralaminar gases which are conducted via the resin layer out of the material via the reinforcement layer. In this way, it is achieved that any entrapped inter- and intralaminar gases can escape via the resin material layer during processing of said material. Any entrapped gases can further escape from fibre tow to fibre tow via a transverse venting route formed by the venting structure. This also prevents the formation of interlaminar and intralaminar voids in the cured product.

In a further embodiment of the invention, the first venting structure may comprise passages or venting

channels. These venting channels allow interlaminar and intralaminar gases to be conducted out of the moulding material via these channels. The venting channels act as conduits for any gases within the resin layer and connect
5 fibres in the reinforcement material via transverse venting routes from fibre to fibre. The conduits provide additional venting routes to any entrapped gases, so that these gases can also escape from the moulding material. The venting channels may extend over the full thickness of the resin
10 material layer. During processing, as the reinforcement material is locally closed off by the resin material, the venting channels connect these pockets to allow the gases to escape the moulding material via the resin layer. This prevents entrapped gas pockets

15 In an embodiment of the invention, the venting structure may be adapted to vent the resin layer in one or more directions. The venting structure may be adapted to be connected to a suitable gas extraction means. A suitable gas extraction means may comprise a vacuum pump in
20 combination with vacuum consumables such as a vacuum bag etc.

In another embodiment, the venting channels may extend substantially in a plane perpendicular to the resin layer. Preferably, the venting channels extend from one side of
25 the resin layer across said layer through to the other side of the resin layer. The venting channels may further extend in a direction which is approximately parallel to the resin layer. In a preferred embodiment, the venting channels may extend from one side of the resin film across the resin
30 film through to the other side of the resin film whereby the end portions of the venting channels are offset relative to one another on either side of the resin layer, so as to maximise the length and volume of the venting channel. This promotes the flow of any laminar gases and
35 entrapped gases out of the moulding material during

processing. Preferably, the venting channels extend from one side of the resin layer across the resin layer to the other side of the resin layer in a zig-zag type fashion. This particular shape of the venting channels allows
5 adequate venting of the areas closed off by the resin during processing, since the zig-zag type channels extend over an as large as possible volume within the resin layer.

In yet another embodiment of the inventions, the resin material layer may be discontinuous with the
10 discontinuities forming the venting passages or channels. In a further embodiment of the invention the resin layer may comprise venting channels defined between lengthwise extending strips of resin material. The strips may extend in a non-linear lengthwise format. The resin strips may be
15 at an approximate angle of 45° or any other suitable angle relative to the direction of the fibres in the reinforcement layer. The strips may be arranged approximately parallel to one another.

In another embodiment of the invention, the first
20 venting structure may comprise venting channels or passages which extend substantially in a plane parallel to the reinforcement layer. The venting structure may be formed by a discontinuous resin layer. The discontinuous resin layer may comprise patches, strips or small areas of resin
25 which are located on the reinforcement material.

In a further embodiment of the inventions, the reinforcement layer may comprise a further venting structure for allowing gases to pass out of said moulding material via the reinforcement layer during processing. The
30 further venting structure may be formed by the reinforcement layer. The reinforcement material may be dry (unimpregnated by the resin) or at least partially dry (partially unimpregnated by the resin) to allow gases to be vented out via the reinforcement layer. In embodiments
35 of the inventions, the moulding material may comprise one

or more resin layers and one or more reinforcement layers. The reinforcement material may be conjoined to the surface of the resin material so as to provide a substantially unimpregnated reinforcement layer.

5 In yet another embodiment of the inventions, there is provided a resin material comprising a venting structure for allowing gases to pass out of said resin material during processing of the material. The resin material may be in the form of a film or a layer. The resin film may be
10 applied to any suitable reinforcement layer to form a moulding material. The reinforcement material may comprise a non-woven reinforcement material such as a unidirectional non-woven reinforcement material. The reinforcement material may also comprise a woven reinforcement material.
15 A further reinforcement material layer may be applied to the resin layer to form the moulding material. In a preferred embodiment, the resin layer may be sandwiched between the reinforcement material layers.

 In another embodiment of the invention, the
20 reinforcement layers are held in place on the resin layer by the inherent tack of the resin material. This obviates the need for stitching, adhesive or binder materials for keeping the moulding material integral during transport and handling including lay-up. This property of the material
25 is particularly useful when the reinforcement material comprises non-woven reinforcement fibres such as unidirectional fibres as no stitching of the material is necessary which would otherwise affect the quality and mechanical properties of the moulding material.

30 In an embodiment, the cosmetic surface quality of the moulding material as hereinbefore described is high in comparison to conventional moulding materials. The first venting structure and/or further venting structure may enable the resin material to completely wet the mould
35 surface during processing whereby any entrapped air and

laminar gases which may be located between the mould surface and the moulding material can escape via the venting structure. Gases may thus escape via the venting structures as provided in the resin layer and/or the reinforcement layer.

In a further embodiment of the inventions, there is provided a method of forming or manufacturing a moulding material as hereinbefore described. The method may comprise the steps of providing a resin material and a means for forming venting channels inside the resin material, the method further comprising the step of forming the venting channels in the resin material to form the gas permeable resin material. The method may further comprise the step of providing means for decreasing the viscosity of the resin material before the venting channels are formed so that the permeating means can permeate the resin material to form the venting channels.

In yet another embodiment of the invention, there is provided a method of forming or manufacturing a permeable resin film comprising the steps of providing a resin film, providing a heating means for increasing the temperature of said resin film thereby decreasing the viscosity of the resin, and providing a means for providing venting channels inside said resin film, said method further comprising the steps of increasing the temperature of said resin film below the temperature for processing the film and piercing said resin film to form said permeable resin film. The venting structure may be provided by piercing means such as comb or needles or some other suitable means.

In an alternative embodiment, after heating and mixing, the resin material may be cast onto a suitable carrier means. Suitable carrier means may comprise a silicon coated carrier member, silicon backing paper or a carrier member comprising a PTFE material. Since the resin film is still at a raised temperature after casting, a

means may permeate the film to form a gas permeable resin film. The resin may also be located onto the carrier member as a discontinuous layer, for example in the form of strips of resin material.

5 In an embodiment of the inventions, a supply means may continuously supply a resin layer towards a venting means for making a gas permeable structure within the resin layer. The venting means continuously applies a venting structure in the resin layer. In a preferred embodiment,
10 the resin film is continuously provided on a transport member, such as a conveyor belt, towards the venting member. The venting or piercing member, which is in contact with the resin film layer, is continuously movable in a direction perpendicular to the direction of travel of the
15 resin film layer. In this way the venting structure is formed.

 In a particular embodiment the venting member comprises a comb which extends through the resin layer and which may be movable in a direction perpendicular to the
20 direction of transport of the resin layer. The resin material is at a temperature whereby the viscosity of the resin is reduced and whereby no curing of the resin material occurs. The viscosity of the resin material is selected such that the viscosity is high enough to prevent
25 the venting channel from closing due to the flow of the resin material, and the viscosity is low enough to prevent too much pressure from being exerted on the comb and to prevent the resin material from clogging the comb.

 The resin film is preferably provided on a backing
30 material to support the resin film during handling and application of the venting structure. The backing material may comprise a silicon paper. Alternatively, the resin material may be located on a conveyor belt such as a PTFE belt which supports the material during transport and
35 handling.

In yet another embodiment of the inventions, there is provided a method for forming a moulding material, comprising the steps of providing a layer of a permeable resin material, and providing a fibrous reinforcement layer, said method further comprising the steps of locating
5 said reinforcement layer in relation to said permeable resin layer to form said moulding material.

There is thus provided a moulding material, a resin material, a method of manufacturing a moulding material,
10 a method of manufacturing a permeable resin material, and an article according to the embodiments of the invention.

We have discovered that moulding materials with an air venting structure, and particularly air venting moulding materials comprising layers of uni-directional
15 reinforcement material, are difficult to process if the processing conditions cannot be carefully controlled. Air is then trapped inside the cured product.

We have discovered that by the creation of gaps which are located inside the reinforcement resin film, entrapped
20 gases can be transported in both horizontal and vertical directions (in both a plane parallel to the resin layer and in a plane perpendicular to the plane of resin layer). The permeable resin film material with gaps or venting channels can be applied as a resin layer to any moulding material
25 and to any other composite materials to enable or improve venting of interlaminar and intralaminar gases.

Preferably, the permeable reinforcement resin material is applied to moulding materials comprising unidirectional reinforcement layers, since these layers are generally
30 difficult to process due to air blocks or traps which can occur in the unidirectional fibrous layers.

We have also discovered that the moulding material as hereinbefore described has a better cosmetic surface quality in comparison to conventional moulding materials.
35 The venting structure improves venting of air, inter- and

intralaminar gases. This enables the resin to completely wet out the mould surface during processing. Upon curing, this results in the enhanced cosmetic surface quality.

5 Venting of the moulding material can further be improved by a discontinuous resin layer. The resin layer may comprise discontinuous strips or areas of a resin material. This greatly enhances venting of the moulding material during processing and promotes flow of the resin material. This prevents the problem of trapped venting
10 paths from occurring.

 The preform moulding material as hereinbefore described has the advantage that it prevents both intralayer voids and interlayer voids from occurring. This results in a void-free moulded product of a superior
15 mechanical and cosmetic quality. The preform moulding material is dry to touch which simplifies handling of the material in comparison with conventional prepregs. Furthermore, since the first and further venting structures are situated within the moulding material, the structures
20 are robust and not affected by accidental clogging or blockage. Also, the moulding material is cost-effectively and production is uncomplicated.

 The preform multi-layered moulding material preferably comprises a layer of a resin material sandwiched between
25 layers of reinforcement material. The reinforcement material comprises a further venting structure. The moulding material is easy to handle due to the absence of resin on the external surface of the material. If locally external surface tack is necessary, for example for
30 applying the moulding material on a vertical surface or standing part of the mould or moulding, local pressure is applied to the material so as to locally impregnate the reinforcement material. In this way, local areas of the material are provided with external surface tack.

35 The invention will now be described by way of example

only, and with reference to the accompanying drawings, in which:

Figure 1 presents a conventional moulding material comprising unidirectional fibres (UD moulding material) in a diagrammatic plan view, and;

Figure 2 presents a diagrammatic perspective view of a moulding material according to an embodiment of the invention.

The moulding material 10 comprises a layer of a resin material 12 sandwiched between layers of unidirectional fibrous reinforcement material 14 whereby the reinforcement material 14 is conjoined to the surfaces of the resin material 12. As shown in Fig. 1, as the moulding material 10 is processed and the reinforcement material 14 starts to be wetted out by the resin 12, the resin 12 tracks through gaps in the reinforcement material first and areas 18 of the uni-directional fibre 14 become trapped off or blocked 20 so that no air transport can occur in directions 22 along the reinforcement fibre and perpendicular to the reinforcement fibre (x, y -direction and z -direction). Any residual laminar gases inside the fibre tows get locked inside the tows which creates void areas in the cured product.

The preform moulding material 100 comprises a first and a second layer of a reinforcement material 102, 104 comprising multiple uni-directional fibre tows 112, and a layer of a resin material 106 arranged between the reinforcement layers 102, 104. The resin material layer 106 comprises a first venting structure to allow gases to pass out of said moulding material 100 via the reinforcement layer 102, 104 during processing. The first venting structure comprises venting channels or breaks in the resin film 108 which extend substantially in a plane perpendicular to the resin layer 106. The venting channels 108 also extend in a direction which is approximately

parallel to the resin layer 106. In this way, the venting channels can extend in a zig-zag type fashion. This increases the volume of the channels which promotes the gas venting properties of the resin layer. The venting channels or resin breaks 108 create air flow in x, y and z-direction 110 from fibre tow 112 to fibre tow 112. Since the reinforcement material layers 102,104 are essentially dry, the reinforcement layers 102,104 comprise a further venting structure formed by the fibre tows to allow gases to pass out of said moulding material 100 via the reinforcement layers 102,104 during processing. The venting channels 108 provide transverse connections in the reinforcement material 102,104 to reconnect closed off areas of the reinforcement material during processing to allow venting of entrapped gases out of the moulding material.

In use, the moulding material is processed in the usual way by increasing the temperature of the resin material 106. Further, a vacuum pressure may be applied over the moulding material 100 to promote the evacuation of gases such as air from the moulding material 100, and to generally promote the flow of the reinforcement resin material 106 into the fibrous reinforcement material 102,104. The vacuum is applied by locating the laminate structure within an enclosure such as a vacuum bag and subsequently a proportion of the air is removed from the enclosure.

During processing, the resin material 106 impregnates the fibrous material 102,104 whereby any entrapped air can escape, both in X-Y directions parallel to the plane of the reinforcement material, and perpendicular thereto in the Z direction. This is possible due to the venting channels 108 which are located within the resin film material 106. The venting channels then close as resin infusion into the reinforce material continues and the moulding material is further processed. This results in a cured product which

is essentially void-free, thereby obviating the problems which were discussed hereinbefore and which are presented in Figure 1 of the drawings.

CLAIMS

1. A multi-layered moulding material comprising:-
a layer of a reinforcement material, and
5 a layer of a resin material, wherein
said resin material comprises a first venting
structure to allow gases to pass out of said moulding
material via the reinforcement layer during
processing.
- 10 2. A moulding material comprising a reinforcement
material and a resin material, the resin material
comprising a first venting structure for venting
gases out of the moulding material during processing.
- 15 3. A moulding material according to claim 1 or 2,
wherein the reinforcement layer comprises a further
venting structure for allowing gases to pass out of
said moulding material via the reinforcement layer
20 during processing.
4. A moulding material according to claim 3,
wherein the further venting structure is formed by
the reinforcement material.
- 25 5. A moulding material according to any of the
preceding claims, wherein said first venting
structure comprises venting passages or venting
channels for venting interlaminar and/or intralaminar
30 gases.
6. A moulding material according to any of the
preceding claims, wherein the resin layer is
discontinuous thereby forming the first venting
35 structure.

7. A moulding material according to any of the preceding claims, wherein the reinforcement material is conjoined to the surface of the resin material.

5

8. A moulding material according to claim 7, wherein the reinforcement material is held in place by the inherent tack of the resin material.

10

9. A moulding material according to any of the preceding claims, wherein the reinforcement material is unimpregnated by the resin material or at least partially unimpregnated by the resin material to allow gases to pass out of the moulding material.

15

10. A method of manufacturing a multi-layered moulding material according to any of claims 1 to 9.

20

11. A method of manufacturing a multi-layered moulding material comprising:

providing a layer of a reinforcement material, and providing a layer of a resin material, said resin material comprising a venting structure to allow gases to pass out of the moulding material via the reinforcement layer during processing,

25

said method further comprising the step of locating said reinforcement material in relation to said resin layer.

30

12. An article comprising a moulding material according to any of claims 1 to 9.

13. A method of manufacturing a gas permeable resin material comprising the steps of:-

35

providing a resin material, and

providing a first venting structure inside said resin material to allow gases to pass out of said moulding material via the reinforcement layer during processing,

5 the method further comprising the step of forming a venting structure in the resin material.

10 14. A method according to claim 13, wherein said method comprises the step of providing piercing means for piercing said resin layer, said method comprising the step of piercing the resin layer to provide the first venting structure.

15 15. A method according to claim 13 or 14, wherein the method comprises the step of providing means for decreasing the viscosity of the resin material, said method further comprising the step of decreasing the viscosity of the resin material before forming the first venting structure.

20 16. A method according to claim 15, wherein the means for decreasing the viscosity of the resin comprise heating means.

25 17. A method according to claim 16, wherein the heating means is adapted to heat said resin layer to a temperature whereby the viscosity of the resin layer is decreased and whereby no curing of the resin layer occurs.

30 18. A method according to any of claims 13 to 17, wherein the resin material is in the form of a film or layer.

35 19. A resin material manufactured in accordance with

a method according to any of claims 13 to 18.

5 20. A resin material comprising a first venting structure adapted to vent gases out of the resin material during processing of the material.

10 21. A resin material according to any of claims 19 or 20, wherein the first venting structure comprises venting channels or venting passages.

22. A resin material according to any of claims 19 to 21, wherein the resin material is discontinuous.

15 23. A method of manufacturing a moulding material comprising:
providing a layer of a resin material according to any of claims 19 to 22, and
providing a layer of a reinforcement material,
said method further comprising the step of
20 locating said resin layer in relation to said reinforcement material.

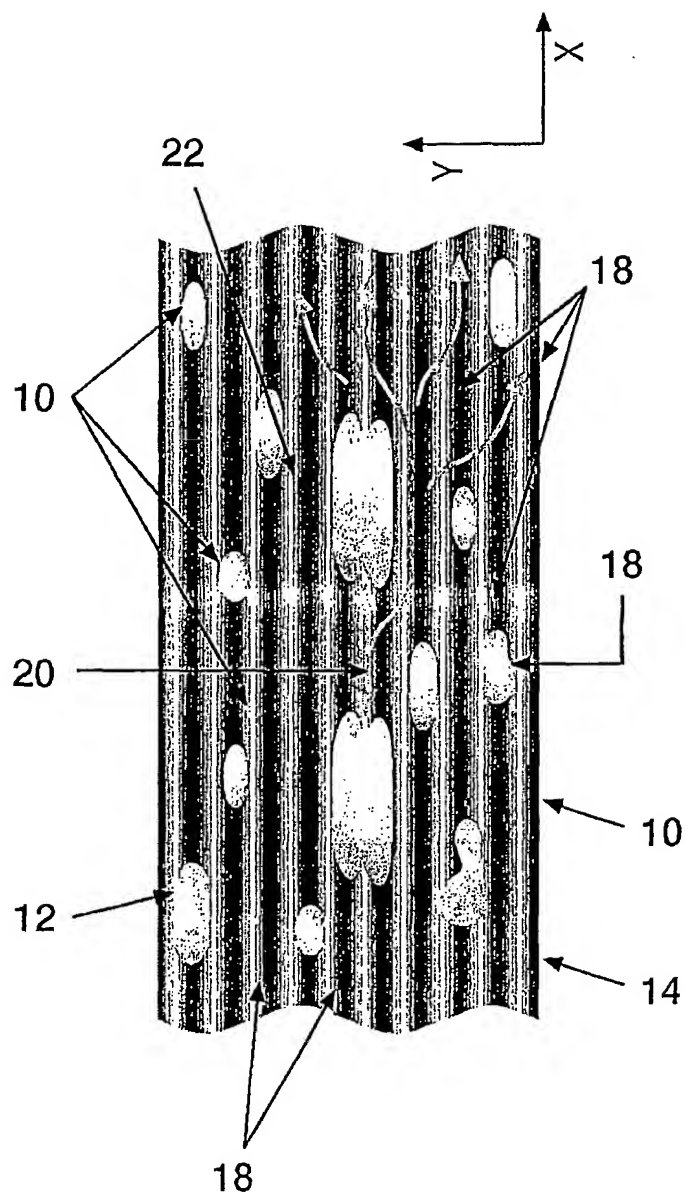


Fig. 1

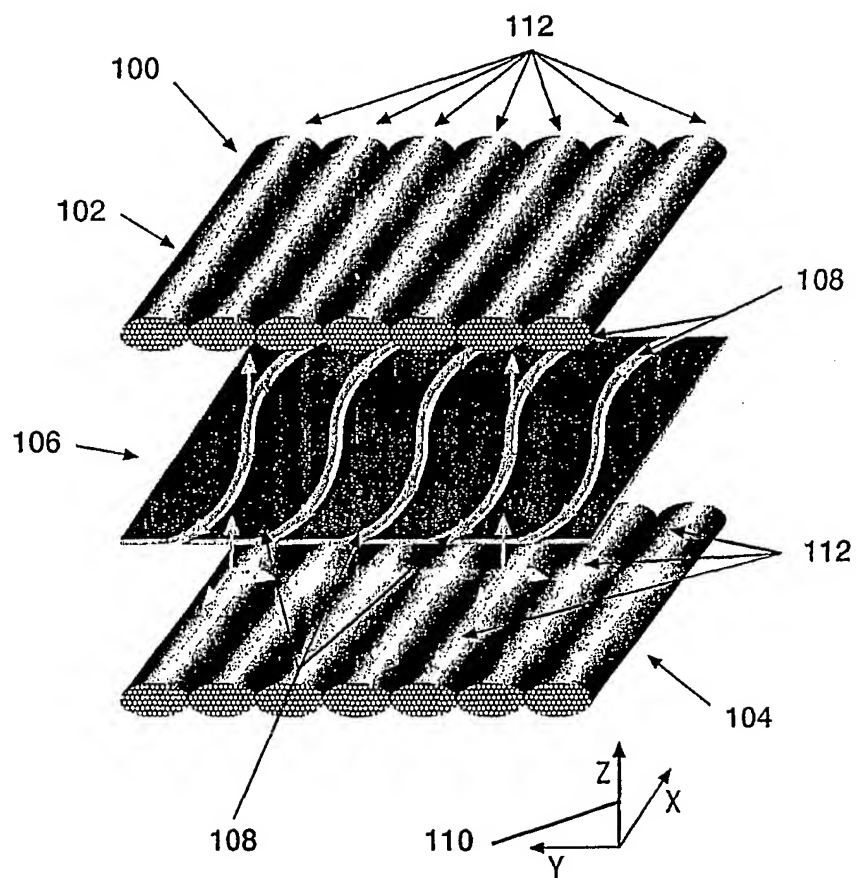


Fig. 2

INTERNATIONAL SEARCH REPORT

PCT/GB 02/02055

A. CLASSIFICATION OF SUBJECT MATTER IPC 7 B29C70/46 B32B27/12 B29C70/54		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) IPC 7 B29C B32B B29B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the International search (name of data base and, where practical, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 32 20 768 A (PELZ ERNST) 8 December 1983 (1983-12-08) page 8, paragraphs 4,5 -page 10, paragraphs 1,2; claims 1,4,6,7; figures 1,2 ---	1,2,5-8, 10-14, 18-23
X	WO 00 27632 A (CRONK PETER ;NESS DEREK (GB); STRUCTURAL POLYMER SYSTEMS LIM (GB)) 18 May 2000 (2000-05-18) cited in the application page 4, line 19-24 -page 5, line 15-18; claims 1,6,10,14,15,18-20; figures 1,2; example 1 page 1, line 30-32 -page 2, line 10 --- -/--	1-13, 15-21,23
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